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A Learning Object Organiser System for Higher Order Thinking

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Abstract

This paper presents a study of the higher order thinking involved in the delivery of computer science courses. The study involved two phases. In the first phase, a preliminary study was conducted to evaluate higher order thinking skills among the computer science students exposed to conventional teaching and learning. The results of the preliminary study revealed an obvious lack in the acquisition of higher order thinking by the students at the end of a course. The second phase of the study involved the development and evaluation of the Web-based learning system that is intended to promote higher order thinking skills in a technology-enabled learning environment. Several attributes of the system were studied, including the usability of the system in terms of its design to support outcome-based learning, learning strategies in promoting higher order thinking skills, collaborative learning, motivation and user control. Despite some weaknesses in the system, the results obtained were quite positive, indicating the potential of such a system to be used on a wider scale for the promotion of higher order thinking skills in computer science education.

Keywords: Learning object, higher order thinking, concept map, conventional teaching and learning, web-based system

Introduction

The advancement of information and communication technology (ICT) has brought with it not only the acquisition of knowledge through the immense amount of resources made available by the technology but also the demand for the development of thinking skills associated with it. Ramirez and Bell (1994) noted that educators must recognise that students require an educational process through ICT that enables them to master the higher order thinking (HOT) skills, which are imperative for solving real-world problems in the workplace. Ivie (1998) highlighted that HOT has not received adequate attention in most teaching and learning approaches.

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The results from studies related to the teaching and learning of computer science courses have shown that many students fail to demonstrate the required thinking skills such as reasoning, analytical thinking and synthesis thinking (Chmura, 1998; Henderson, 1986). Consequently, concern has been raised that many graduates fail to meet the requirements and expectations of the workplace due to a lack of these skills (Wallis and Steptoe, 2006).

Due to the importance of HOT, this study presents a development and evaluation of a Web-based system that is intended to promote and encourage HOT in the teaching and learning of computer science courses. In doing so, this paper first presents the background of HOT as well as the problems arising from the lack of HOT skills. A study is presented that looks at the extent to which HOT is incorporated into the conventional teaching and learning of a computer science course. Accordingly, the design and development of a prototype Web-based learning system, which is designed to support and promote HOT in teaching and learning processes, are presented. A feasibility study was conducted to elucidate the students' attitudes pertaining to the system in the support of outcome-based learning, the learning strategies deployed in the promotion of HOT, the ensuing collaborative learning and the students' motivation.

Higher Order Thinking

Most researchers relate HOT to Bloom's taxonomy in the categorisation of thinking skills. This taxonomy is a popular instructional model developed by Bloom et al. (1956). It categorises thinking skills from concrete to abstract using the following categories:

1. Knowledge
2. Comprehension
3. Application
4. Analysis
5. Synthesis
6. Evaluation

When focusing on the higher order cognitive operation, most studies have widely considered the last three categories of Bloom's taxonomy, namely, analysis, synthesis and evaluation, as HOT skills (Cradler et al*.,* 2002; Tal and Hochberg, 2003; Ivie, 1998; Quellmalz, 1987; Yuretich, 2004; Eken, 2002; Hopson, Simms and Knezek, 2001; Newmann and Wehlage, 1993; Tan, Baharuddin and Mohd. Salleh, 2009).

Analysis is the ability to break down the constituent parts of materials into the relative hierarchy of ideas with the relationships among the ideas being illustrated. This may include the identification of parts and the hierarchical organisation as well as the analysis of the relationships among the parts themselves. The learning outcomes from this skill are higher than the learning outcomes from knowledge, comprehension and application skills. Analysis is therefore recognised as a cognitive operation of HOT.

Synthesis, on the other hand, is the ability to put parts together to form a whole. This involves the process of working with parts and arranging and combining them in such a way as to constitute a new pattern or structure. The learning outcomes emphasise the formation of new patterns or structures and creative behaviour. Synthesis is also recognised as a cognitive operation of HOT.

Evaluation is defined as the ability to judge the values of materials for some purposes, ideas, solutions, etc. The judgements are based on definite criteria, either those determined by the students or those given to them. The learning outcomes belong to the highest cognitive hierarchy, and they are also recognised as a cognitive operation of HOT.

Taking into consideration the three categories, HOT thus requires students to manipulate information and ideas in ways that transform their meaning and implication. This occurs when students combine facts and ideas to analyse, synthesise and evaluate them to form some generalisation of knowledge. The manipulation of information and ideas through these processes allows students to solve problems, generate knowledge and promote understanding.

HOT and Computer Science Education

Considerable research has been conducted to study the teaching and learning processes in computer science courses. Empirical results from some of the studies show that many students – upon the completion of their courses – fail to demonstrate required skills such as reasoning, analytical thinking, synthesis thinking, problem solving and logical thinking (Chmura, 1998; Henderson, 1986). Instead of acquiring the analysis, synthesis and evaluation thinking skills for solving problems, many students memorise facts from their learning and thus resort to trial and error when confronted with real world problems. This phenomenon is partly due to the teaching and learning approach in the delivery of the computer science courses, which lack the critical elements that promote HOT; the students are thus unable to apply the problem solving and logical reasoning skills required for solving workplace problems (Parham, 2003; Arup, 2004).

The importance of HOT in the students' achievement when learning computer science in courses has received the attention of researchers. Parham (2003), for instance, showed that there is a direct correlation between the students' HOT skills and their academic performance. Hadjerrouit (1999) noted that the conventional predominant model of instruction that views learning as the passive transmission of knowledge causes serious misconceptions and a lack of conceptual understanding in computer science learning. This theory is further supported by Arup (2004), who found that the existing learning approaches in computer science course resort to the regurgitation of what the instructors have taught, implying the absence of ability among the students to use HOT skills. These approaches tend to encourage the students to embrace the process of remembering what the instructors teach and present in the classroom and do not inculcate the ability to think independently on the part of the students.

Another major problem confronting computer science students is the lack of deep understanding of the relationships in the facts they learn (Scragg, Baldwin and Koomen, 1994; Mirmotahari, Holmboe and Kaasboll, 2003). Students are better in practical skills than in theories. In computer education, a student's prior knowledge is the foundation for further knowledge construction, and prior knowledge can interfere with the development of new concepts (Holmboe, 1999; White, 2001; Mirmotahari, Holmboe and Kaasboll, 2003; Scragg, 1991). New information must be linked to information already understood (Rosenberg, 1976; Mohammad Khalid, Bassem and Marcovitz, 2000). In this context, learners generate and evaluate ideas that might have been created or inherited from their prior knowledge and retain those that are correct after their evaluations. All of these activities are related to HOT.

The rapid development of computer-related technology demands that computer science education stays abreast of rapid changes. The growth of knowledge in computer-related technology requires increasing timeliness in teaching resources, expertise and preparation time (Wolffe et al., 2002). Thus, students are exposed to a larger amount of information pertaining to their fields. Instructors and students have been burdened with the task of communicating a large amount of rapidly changing content. Consequently, over-emphasis on the content has resulted in the lack of attention on HOT that is necessary for students to deal successfully with complex scenarios (Arup, 2004). In the workplace, computer science graduates must be able to solve problems that require them to analyse complex scenarios and synthesise and evaluate their arguments, both of which are HOT-related activities.

A Study of HOT in Conventional Teaching and Learning

The aim of the first part of this study was to identify the level of HOT skills among computer science students learning computer science in courses with conventional teaching and learning. The course involved was entitled "The Computer System" and is offered to first year students in a college in Malaysia. It is an important introductory topic in computer science that provides knowledge of the vocabulary, fundamental concepts and information sources (Rosenberg, 1976). Due to the nature of the course, it is imperative to promote HOT among the students in the early learning stage before they proceed to higher level computer science courses.

The methods used in the study were first to interview the lecturers. Three lecturers who had taught the course were involved, and interviews were conducted to identify the teaching method employed by them in delivering the course and the extent to which HOT was incorporated into the teaching method.

The analysis of the interviews found that the main approach undertaken by the lecturers was lecturing and providing a predetermined structure of notes using PowerPoint presentations. In addition to these, the lecturers also provided additional materials and resources from the Internet to supplement the learning. The students were given an assignment for which they were required to prepare a report based on a designated topic. The analysis also revealed that the problem in the learning of this course was that the learners could hardly see the relationships and linkages between the sub-topics and the concepts they had learned. As a consequence, they encountered difficulty in comprehending and understanding these concepts. This finding is consistent with the findings of Scragg, Baldwin and Koomen (1994) and Mirmotahari, Holmboe and Kaasboll (2003).

The level of HOT achieved by students in this teaching method was determined by analysing the answer scripts of 64 students in the final examination of the course. A rubric of HOT evaluation was modified with permission from Hansen (2001) and appropriately validated. The modifications of the rubric were based on the taxonomy of thinking skills of Bloom et al. (1956) and Bloom et al. (1971). There were five scores in the rubric, and each score represented a different criterion of the examination answers. The maximum score was 4, and the minimum was 0. Rubrics have been used widely in the research of HOT skills assessments. An example of the self-designed HOT assessment instrument based on Bloom's taxonomy is the Rubric of Higher Order Thinking Evaluation of Bell, Allen and Brennan (2001). There are also other HOT rubric assessments such as those by Hogan, Nastasi and Pressley (2000), Tal and Hochberg (2003) and Zoller (1999).

There were three essay questions in the final examination of the course, and each question consisted of six sub-questions. Each sub-question represented a different component of a cognitive operation of Bloom's taxonomy: knowledge (K), comprehension (C), application (App), analysis (Ana), synthesis (S) and evaluation (E), as tabulated in Table 1.

Based on the rubric, the mean scores of the students' cognitive operation of Bloom's taxonomy in each question in their final examination were recorded. From Figure 1, it is evident that the mean scores for the operation of knowledge, comprehension and application were higher than the mean scores for analysis, synthesis and evaluation. These results indicated that most of the students scored higher in the questions for the first three thinking skills, which are commonly referred to as the Lower Order Thinking (LOT) skills (Bloom et al., 1956).

Table 1: The number of questions according to Bloom's taxonomy

Component of Thinking No. of Question	K	C	App	Ana	S	E	Total
1	1	1	1	1	1	1	6
2	1	1	1	1	1	1	6
3	1	1	1	1	1	1	6
Total no. of questions	3	3	3	3	3	3	18
Percentage (%)	16.67	16.67	16.67	16.67	16.67	16.67	100

Notes: knowledge (K), comprehension (C), application (App), analysis (Ana), synthesis (S) and evaluation (E)

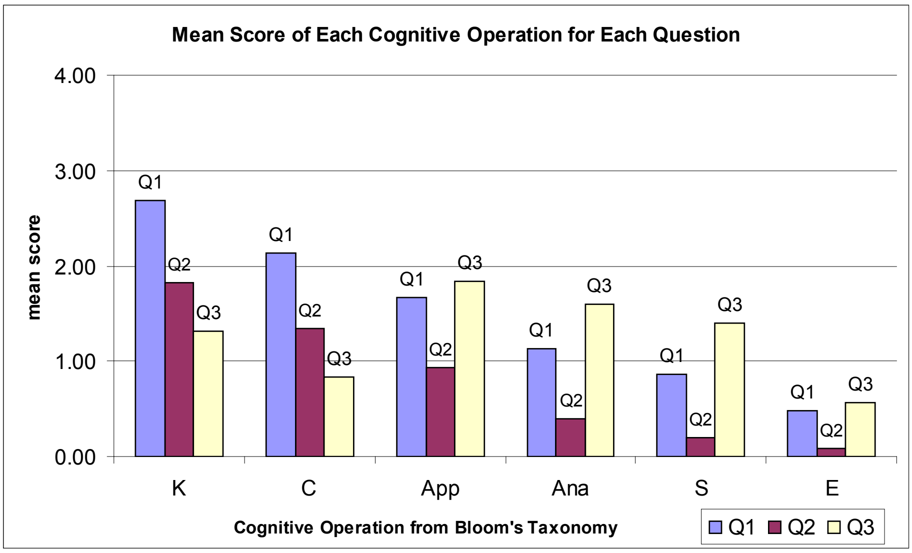

Figure 1: Mean scores for the components of thinking skills in Bloom's taxonomy for each question

Notes: knowledge (K), comprehension (C), application (App), analysis (Ana), synthesis (S) and evaluation (E)

Figure 2 shows the students' scores and percentages of each cognitive operation for all of the questions. The figure shows that the highest percentage of scores for the component of thinking was knowledge, which was 49%, and the lowest was evaluation, which was only 9%. Results from the analysis of the level of HOT among the students indicated that most of them were unable to answer questions that required them to use HOT (analysis, synthesis, evaluation). However, they were able to answer the questions of LOT (knowledge, comprehension, application). In other words, most of the students subjected to conventional teaching and learning, which focused on lecturer-centred rote lecturing and behaviourism-based assessments, such as assignments and tests, were deficient in HOT. This result is consistent with the findings of Parham (2003), Chmura (1998), Henderson (1986) and Arup (2004), who found that rote lecturing results in students who are unable to demonstrate HOT in their learning outcomes.

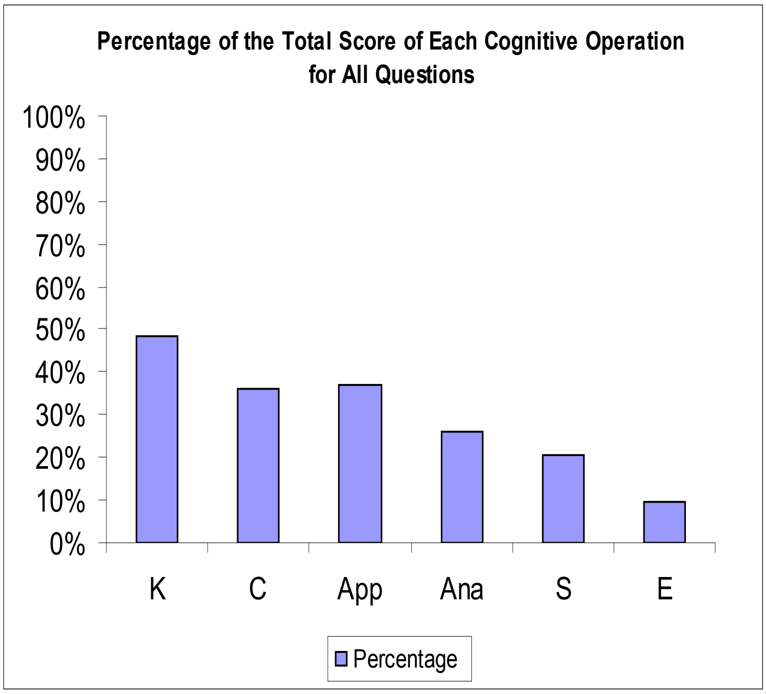

Figure 2: Percentage of the total scores for each component of thinking of all questions

Notes: knowledge (K), comprehension (C), application (App), analysis (Ana), synthesis (S) and evaluation (E)

MELOR: A Prototype Web-Based Learning System to Promote HOT

The aims of the second part of the study were to develop a web-based learning system called the Malaysian E-learning Object Repository (MELOR) system, which is intended to engage students in HOT skills in learning, and subsequently, to evaluate the system. The MELOR system is developed based on a multi-facet theoretical design that incorporates three important components, namely, the learning object, concept mapping and collaborative learning (Tan et al., 2008).

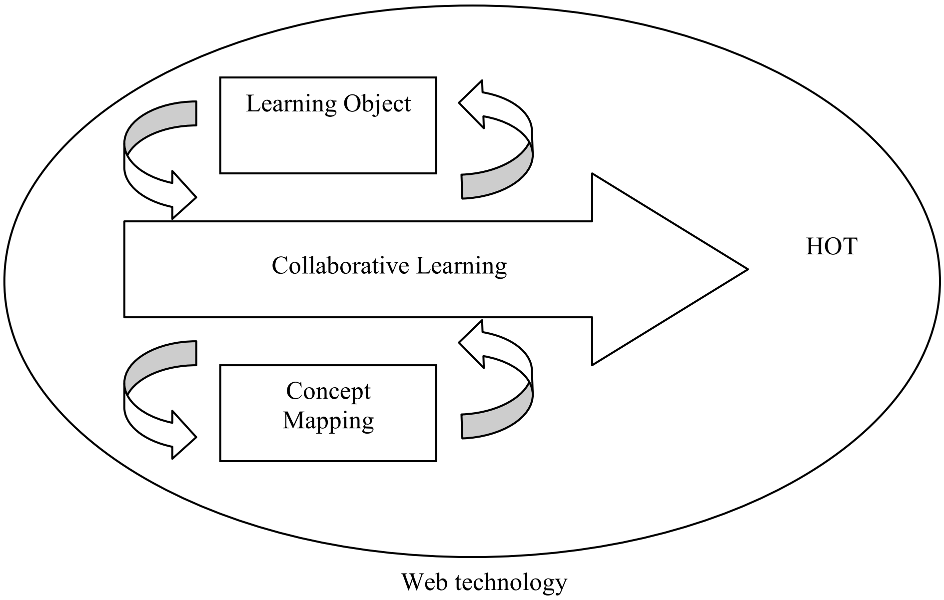

Figure 3: Theoretical framework of MELOR design and development

The Learning Object

A learning object is any digital resource that can be reused to support learning (Wiley, 2000). To date, the discussion of learning objects is commonly associated with the concerns for establishing standards and mainly focuses on the technical issues about these learning objects (Singh, 2000; Wiley, 2002; Bannan-Ritland, Dabbagh and Murphy, 2000). Most current developments of the learning objects in e-learning have overlooked the use of these objects to support learning (Bannan-Ritland, Dabbagh and Murphy, 2000; Shi et al., 2004; Tan, Baharuddin and Mohd. Salleh, 2009).

With the unique attributes of the learning objects in providing a customised, individualised and flexible learning environment, the required approach can be grounded in constructivist principles of a learner-centred and learner-controlled learning environment. Collis and Strijker (2003) noted that the learning objects result in a pedagogical shift from the emphasis on learning as acquisition of predetermined contents towards the emphasis of learning as participating and contributing to the learning experience. Learners construct their own understanding when experiencing the learning objects and undertake activities by organising, analysing, synthesising and evaluating knowledge in a self-directed fashion rather than in a predetermined structure from the instructors. This view of learning fits well with the constructivist's learning theory. The learning objects are commonly seen in association with a relatively new idea of a learning model called generative learning. In fact, many researchers have suggested that generative learning is an important constructivist learning (see, for example, Bannan-Ritland, Dabbagh and Murphy, 2000; Dunlap and Grabinger, 1996; Duffy and Jonassen, 1992; Morrison and Collins, 1996; Grabowski, 1996; Bonn and Grabowski, 2001).

Concept Mapping

The second component of the system is concept mapping. A concept map is an important tool for generative learning (Grabowski, 1996; Osborne and Wittrock, 1983; Bannan-Ritland, Dabbagh and Murphy, 2000). The generative learning strategies include the generation of a relationship organisation between different concepts such as concept mapping (Grabowski, 1996). This requires the deeper processing of learning and results in HOT (Dunlap and Grabinger, 1996). Ritchie and Volkl (2000) noted that concept mapping is a valuable and effective generative learning strategy, and this has been validated by their findings on the scores of students in their achievement tests. The positive results gained from the research conducted by O'Reilly and Samarawickrema (2003) about the significant use of the multimedia concept map in enhancing learning confirms this possibility.

The concept map in the MELOR system thus acts as a cognitive tool that engages students in HOT. With it, learners act as designers in the learning process (Jonassen, 1994; Jonassen and Reeves, 1996) and they are given the opportunity to construct or design their own meaning from this learning. This system is very much in line with the study by Jonassen, Mayes and McAleese (1993), which found that individuals seem to learn the most from the design of instructional materials and thereby develop HOT.

To facilitate HOT through concept mapping, the system is designed to offer learners the opportunity to construct or re-construct their knowledge by combining new knowledge with their existing knowledge through concept mapping. It provides a tool that is capable of representing a student's knowledge more comprehensively and allows learners to learn through the design. The system contains a Learning Object Search Engine, a Learning Object Library and a Learning Object Organiser (LOO) which facilitate the design of concept mapping in an outline form.

Learners search the learning objects from the Learning Object Repository (LOR) and the searched results is displayed in a table that contains a description of the learning. Learners can preview the learning objects before they use them for concept mapping. The learning objects selected for the learning are added to the Learning Object Library.

The LOO is a concept mapping tool that can represent the students' knowledge more comprehensively, and it allows them to learn by designing their concept map (see Figure 4). The LOO provides the representation of the concept organisation in an outline form of the concept map. This design has been modified from the concept map software, *Webster*, from Alpert and Grueneberg (2000) and Alpert (2003). The concept map in the system we designed requires the students to create a crosslink between the concepts that are not in the system from Alpert and Grueneberg (2000) and Alpert (2003). Searching crosslinks and indicating the relationships between the concepts involves the students in synthesis thinking (Jonassen, 2000; Dabbagh, 2001; Alpert and Grueneberg, 2000).

The LOO involves students in the design of the concept map of a lesson that contains propositions and concepts linked to various learning objects stored in the LOR. When the students design the concept map, they organise the learning objects, generate the relationships among the learning objects and assimilate the new learning objects into their existing concept map, as shown in Figure 4. This process involves generating links, relating learning objects, adapting the existing learning objects to the new learning objects and correcting any misconceptions in the existing concept map. This assists the students to learn the concepts in a meaningful way and engages them in HOT.

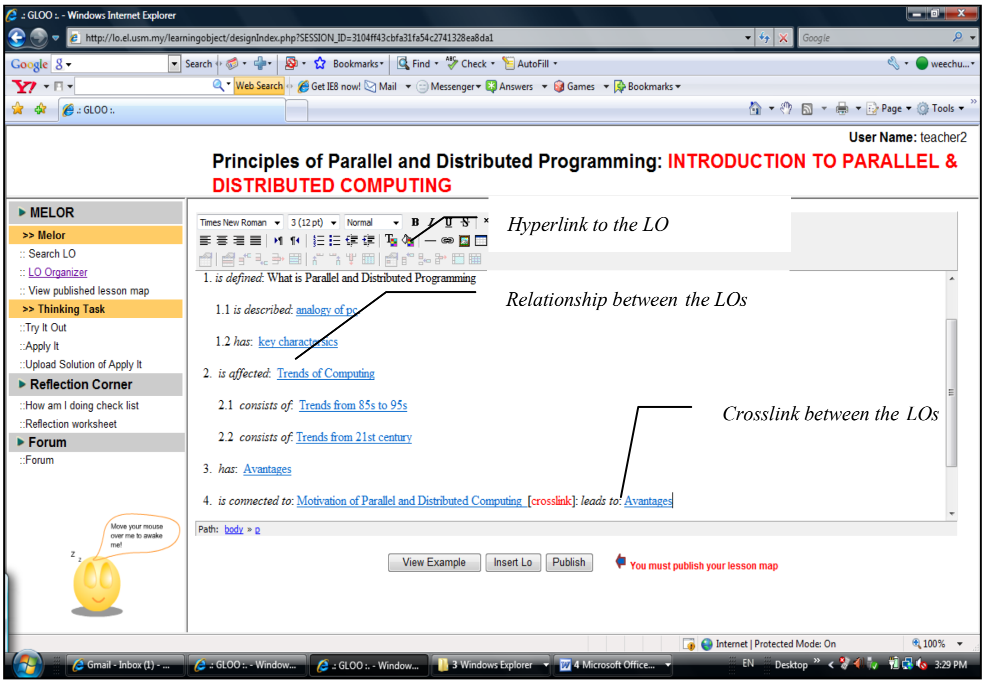

Figure 4: The learning object organiser

Collaborative Tools

The collaborative tools form the third component of the system. A collaborative tool embedded in the system is the forum board. The forum board provides a platform for collaborative teacher-learner and learner-learner discussions to support learning. Collaboration is an essential ingredient for an effective learning environment as it provides learners with the opportunity to discuss, argue, negotiate and reflect upon existing beliefs and knowledge. Using the collaborative tools, the learners construct knowledge through a process of discussion and interaction with learning peers and experts (Harasim, 1989; Alvi, 1994). In other words, learning takes place in an active and interactive environment. During the entire collaboration, the instructor occasionally participates and plays the role of facilitator, guiding and monitoring the entire collaborative process.

The Study on Students' Attitudes towards the MELOR System

A preliminary evaluation of the MELOR system was conducted by looking at students' attitudes towards the system in supporting outcome-based learning, learning strategies in promoting HOT, collaborative learning, motivation and user control. The sample of the study covered 11 undergraduate students enrolled for the course entitled “The Principles of Parallel and Distributed Programming” offered by the School of Computer Sciences, Universiti Sains Malaysia. An introduction session and training using the MELOR system were given to the students. A demonstration on how the system operates was given, and this was followed by hands-on training on how to design the outline-based concept map and upload the learning objects. A hard copy of the user manual was given to the students. The learning process utilising the system lasted for three weeks and involved the learning of Chapter 1 and Chapter 2 of the course. During the learning process, the students were encouraged to use the forum board to collaborate with each other. The lecturer also participated in the forum board to facilitate the learning process.

At the end of the three-week learning period, evaluation forms were administered to the students. Each evaluation form consisted of four dimensions, namely, the attributes related to outcome-based learning: the learning strategy design in promoting HOT, collaborative learning and motivation and user control. Each item was graded on a scale, from 1 representing “strongly disagree” to 5 representing “strongly agree”.

The analysis involved evaluating the mean of each of the dimensions. A high mean represented a high degree of agreement, and a low mean indicated a low degree of agreement. The results of the analysis are depicted in Table 2. The table shows that the highest mean was 3.36, which indicated that the respondents moderately agreed with the system’s ability to support outcome-based learning. This was followed by the learning strategy design in promoting HOT, which recorded a mean of 3.1818. The overall attitude of the students towards the system was quite positive, which was indicated by the overall average mean score of 3.1818.

Table 2: Means and standard deviations of each section

Section	Dimension	Mean	Standard Deviation
A	Outcome-Based Learning	3.364	0.729
B	Learning Strategy in Promoting HOT	3.182	0.884
C	Collaborative Learning	3.164	0.938
D	Motivation and User Control	3.018	0.913
	Average	3.182	0.866

The evaluation form also contained six open-ended questions. These questions were administered to obtain comments and feedback from the students about the system. The data were analysed based on the identification of themes. The summary of the findings was as follows:

1. Most of the students preferred the flexibility of learning objects in the system that helped them to understand topics better.
2. Most of the students disliked the complicated tasks they were required to complete to design the concept map. In addition, the poor user interface design of the system was confusing to the students.
3. Most of the students agreed that the system was able to improve HOT and assist them in learning the topics. Among the reasons given were that the LOO helped them to summarise and revise what they had learned. The LOR provided resourceful learning materials for them.
4. Many suggested that the interface design of the system should be improved to be simpler and more user-friendly.

Discussion and Conclusion

The acquisition of knowledge and concepts in the teaching and learning of computer science courses is important, particularly with rapidly changing technology. Computer science students must be able to stay abreast of changing trends and technology as most of the contents in their courses are based on the latest developments in computer-related technology. This means that students must be very proficient in HOT. Several studies have demonstrated the positive effects of the relationships between HOT and students' achievements in computer science learning. Findings from this study show that in conventional teaching and learning, there is a lack of emphasis on the students' ability in HOT. In addition, the results show that almost all of the students are weak in HOT. HOT is a common practice in a rapidly changing technological society especially for students in the computing field. Thus, this issue must be treated seriously.

The MELOR learning system is designed and developed with the intention of promoting HOT. It provides a learning environment that contains various mind tools embedded within it as defined by Jonassen (1996) and Jonassen and Reeve (1996), with the primary aim of encouraging HOT. The study on the attitudes of the computer science students utilising the system demonstrates its potential in facilitating HOT in the learning of computer science courses through the use of concept mapping and the LOO. The potential of this system is immense, and if appropriately utilised by students, it offers an alternative to other technology-supported learning tools to promote HOT among the students.

There are areas for further research and development to implement the system for wider use. First, it is essential to improve the user interface design of the system so that it is more user-friendly for the students. The interactive graphical-based concept mapping tool that needs to be incorporated should be visually appealing to the users and at the same time, this will result in a more easily constructed concept map. In addition, the task flow in the system should be improved to better automate the learning activities.

The present students' attitudinal study of the system involved a sample of 11 students. A study with a larger student sample should be conducted to elucidate the effectiveness of various attributes of the system in promoting HOT; in particular, other learning designs should be considered to utilise the array of learning tools embedded within them. This study also needs to be replicated using different computer science subjects to establish the generalised usability of the system for the promotion of HOT in computer science education.

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